SURFACE MOUNT MAGNETIC CORE WINDING STRUCTURE

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/422,917, filed October 31, 2002, which is incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates in general to surface mount inductors, and more particularly to a method and corresponding structure including conductors shaped to surround a magnetic core to form, in conjunction with traces on a PCB, the inductor's winding. The conductors are also shaped for efficient positioning and soldering on the PCB using automated equipment.

BACKGROUND OF THE INVENTION

A typical magnetic core winding structure for an inductor typically includes a ferrite core that is wound with wire using a header or bobbin that holds both the wire and the core in the desired position. The trend in modern technology is towards higher density and lower profile electrical devices. A common disadvantage of known magnetic core winding structures and methods having a bobbin or header is that these structures have substantial height and are therefore not desirable for low profile applications such as for inductors mounted on a printed circuit board (PCB).

Known inductors include rectangular magnetic cores that have specially defined surface features for retaining the current conducting pieces that form the inductor's winding. These specially defined features result in a structure that is not easily assembled, thereby increasing manufacturing time and cost. For these known devices, the free flux from the core ends can pass through the copper traces of the PCB producing eddy current losses. This flux leakage also induces noise currents and electromagnetic interference (EMI) that can interfere with other signals on the PCB. In addition, two or more such rectangular core devices are typically used to form a magnetic circuit

providing a return flux path, thereby increasing cost compared to devices requiring only a single core. Additionally, these known rectangular inductor structures have power handling limitations due to their open core design, winding structure, and core size limitations.

The above described surface features of rectangular cores are typically shaped so that the conductors can be pressed into grooves on the sides of the core. This limits the thickness of the conductor since a thick conductor would damage the core during the pressing process. The thin rectangular shape of such known inductors has the disadvantage that it causes bowing as the length increases.

Known prior art methods and structures for forming inductors also utilize toroidal cores, rather than rectangular cores, and conductive strips, rather than wires, for the windings. The conductive strips of these prior art structures have a substantially uniform cross-section and require the use of a lead frame. Such resulting prior art structure requires substantial post processing during manufacturing in order to remove the lead frame without causing damage to the remaining structure. As a result, these prior art structures and methods are costly due to the increased manufacturing time and complexity necessitated by the need to remove the lead frame. In addition, these known structures do not achieve the lowest resistance for a given toroid dimension.

A method and corresponding device are therefore needed that will enable use of a magnetic core winding in low profile applications while reducing flux leakage, component cost, and manufacturing cost by being suitable for automated PCB solder flow processes.

SUMMARY OF THE INVENTION

The present invention solves the above described drawbacks of known devices and methods by providing a method for forming an inductor and a corresponding inductor structure comprising conductors shaped to surround a magnetic core to form, in conjunction with traces on a PCB, a winding on the core. In a preferred embodiment, the inventive inductor includes a toroidal core. The inventive structure is shaped to enable efficient insertion and soldering of the conductors on the PCB using standard automated

equipment. In the inventive method and structure, conductors are fastened to appropriately patterned traces on the PCB to surround a single magnetic core positioned on the surface of the PCB. The inventive method and structure reduces component and manufacturing cost by providing substantially pie-slice shaped conductors that are shaped for efficient automatic positioning and to enable the conductors to be soldered in place during the reflow process for the entire printed circuit board. As a result, a low profile surface mounted structure is provided. Flux leakage is also reduced compared to known magnetic core winding structures.

The inventive method and corresponding structure according to the present invention includes conductors that can be custom designed for any core shape, size, and power rating. In an alternate embodiment, the conductors are preassembled to create a single unit for placing on a PCB using automated equipment.

The present invention includes conductors that can be placed on a PCB in a stable configuration using automatic insertion equipment. The conductors have an inventive shape having a cross section that varies substantially radially with respect to the toroid in order to provide more mechanical stability and to have the lowest resistance for a given toroid dimension. This increased stability results from the aspect ratio of the inventive shaped conductors being such that, once a conductor is placed on the PCB, it is not prone to tip over. Known prior art conductors lack such stability and as a result, must be formed into a lead frame. Without such a lead frame, the prior art conductors would not be stable in a production environment.

Another advantage of the present invention is that, unlike the prior art, the amount of magnetic core material that is visible between adjacent conductors is minimized. The inventive method and structure enables the conductors to be shaped so as to minimize the space between adjacent conductors, which provides the advantage of reduced flux leakage.

Another advantage of the present invention is that the resulting structure is substantially more rigid and allows the core to be captured by the conductors themselves, and therefore does not require adhesive to bond the core to the PCB as required for prior art methods.

An additional advantage of one embodiment of the present invention is that it

provides for the preassembly of the conductors in a single potted unit which enables easy placement of the conductors on the PCB by automatic insertion equipment. The device and corresponding method of the present invention also makes use of distributed gap cores, such as powdered metal cores, that have the advantage of retaining most of the flux in the core.

An additional advantage of one embodiment of the present invention is the winding limitation of the known rectangular designs is avoided since, according to the present invention, the windings are fitted over the core so as to enable the availability of a much wider and thicker copper conductor, for carrying the required current.

The present invention also has the advantage of reducing inductor cost by requiring only a single core of a type widely available from a number of sources.

The present invention also has the advantage of not being limited in size as a result of the large aspect ratio of known rectangular designs.

Another advantage of the present invention is that the conductors are not pressed into grooves on the sides of the core like known rectangular inductor designs, and therefore the conductors are not limited in dimension or thickness on this basis. The conductors are limited by the PCB trace dimensions that the conductors connect to; however, thicker copper, multiple layers, or formed copper pieces can be used to supplement current carrying capacity of the PCB traces. The inventive structure and method enables the conductors to provide both an electrical conductor for the magnetic core and a way to fasten the core to a PCB.

Another advantage of the present invention is that it enables reduced height as compared to devices having a bobbin or header such that the present invention is particularly desirable for low profile applications.

Additional advantages of the present invention are that the present invention spreads the magnetizing field uniformly over the core, reduces AC losses created by a larger surface area; and spreads the heat energy over a larger surface area so as to enable a lower operating temperature and to provide a heat sink for the core.

Broadly stated, the present invention provides an inductor formed on a printed circuit board and a corresponding method, the inductor comprising a plurality of conductive traces on a surface of the printed circuit board; a single magnetic core

positioned on the surface over the conductive traces; and a plurality of pie-slice shaped conductors positioned on the traces, wherein each of the plurality of pie-slice shaped conductors is fastened in offset fashion to a corresponding pair of the conductive traces to surround the core so as to create a coil.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and attendant advantages of the present invention will become more readily appreciated by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of an embodiment of the surface mount magnetic core winding structure according to the present invention as attached to a printed circuit board;

FIG. 2 illustrates the traces on a surface of the printed circuit board according to a preferred embodiment of the present invention;

FIG. 3 illustrates a core positioned on the surface of the PCB over the traces shown in FIG. 2;

FIG. 4 illustrates an exemplary embodiment of the surface of a printed circuit board having traces thereon as shown in FIG. 2 according to the present invention;

FIG. 5 is a top view of an embodiment of the conductors according to the present invention;

FIG. 6 illustrates an upper perspective view of the conductor of FIG. 5;

FIG. 7 illustrates a side view of the conductor of FIG. 5;

FIG. 8 illustrates a side perspective view of the conductor of FIG. 5;

FIG. 9 is a perspective view of a partially assembled inductor according to an exemplary embodiment of the present invention, showing three conductors positioned around a core on a printed circuit board;

FIG. 10 is a perspective view of a fully assembled inductor according to an embodiment of the present invention illustrating the placement of the remaining three conductors around the core assembly shown in FIG. 9;

FIG. 11 is a top perspective view of the method and corresponding structure according to an alternative embodiment of the present invention wherein the conductors are preassembled as a single unit preferably using a non-conductive potting compound for automated placement on the PCB; and

FIG. 12 is a bottom perspective view of the embodiment of FIG. 11.

Reference symbols are used in the Figures to indicate certain components, aspects or features shown therein, with reference symbols common to more than one Figure indicating like components, aspects or features shown therein.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in more detail with reference to the Figures. FIG. 1 is a perspective view of an embodiment of the assembly 10 according to the present invention formed on the surface 11 of a printed circuit board 16, or the like. As shown in FIG. 1, the assembly 10 has a surface mount magnetic core winding structure 18 attached to surface 11. Structure 18 has a plurality of substantially pie-slice shaped conductors 12 surrounding a core 14. The conductors 12 form the top half turn of a full turn of a coil winding, while traces on surface 11 (shown in FIG. 2) form the bottom half of each turn. One pie-slice shaped conductor 12 is used for each winding loop.

FIG. 2 illustrates the printed circuit board traces according to a preferred embodiment of the present invention, prior to the surface mounting of the winding structure 18 thereon. As shown in FIG. 2, the printed circuit board 16 has a surface 11 having a plurality of traces 22 thereon. As also shown in FIG. 2, the traces 22 each have an offset near the center 24 such that a coil effect of interconnected windings is created when the structure 18 is positioned thereon. In an alternate embodiment of the present invention, the same effect is achieved by forming the offset as part of the structure 18. In this embodiment, the traces 22 on surface 11 of PCB 16 are not offset. FIG. 3 illustrates the core 14 positioned on the surface 11 of PCB 16 over the traces 22 shown in FIG. 2. The core 14 is preferably a toroidal core composed of a ferrite material. However; any suitably shaped core may be used. Alternately, core 14 may be composed of a non-ferrite

material, in which case a suitable dielectric coating is used to insulate the core from the traces 22.

FIG. 4 illustrates an exemplary embodiment 30 of the component side of an exemplary PCB 16 including offset traces 22 shown in FIG. 2. FIG. 4 illustrates terminals formed to enable connection of the ends of the coil, formed using the present invention, to the rest of the circuit on PCB 16. FIG. 4 shows a one trace 22 separated electrically into two portions in order to provide terminals 26 and 28 (shown schematically in FIG. 4). In this exemplary embodiment 30, one of the plurality of conductors is placed to connect between an offset center pad 38 and the adjacent trace 22 (shown below pad 38 in FIG. 4) to form one end of the coil which is connected to terminal 26. A separate conductor is placed such that a connection is made between terminal 28 and an offset center pad 48 to form the other end of the coil. Terminals 26 and 28 thus provide a path to enable connection of the coil, formed using the present invention, to the rest of the circuit on PCB 16. Alternately, one of ordinary skill in the art would recognize that a tapped inductor (autotransformer) may be formed using the present invention by simply making another electrical connection on one of the other turns, thereby forming a three terminal device. Furthermore, one of ordinary skill in the art would recognize that a transformer may be realized using the present invention by having one or more additional breaks in the windings and appropriate electrical connections on the turns.

FIGs. 5-8 illustrate views of an exemplary embodiment 32 according to the present invention of the substantially pie-slice shaped conductors 12 shown in FIG. All measurements shown are merely exemplary; the present invention is not limited to the specific dimensions shown. The conductors are composed of a conductive material, preferably copper. FIG. 5 is a top view of an embodiment of the substantially pie-slice shaped conductor piece 32 according to the present invention. FIG. 6 illustrates an upper perspective view of the conductor 32 of FIG. 5. FIG. 7 illustrates a side view of the conductor 32 of FIG. 5. FIG. 8 illustrates a side perspective view of the conductor 32 of FIG. 5. The conductors have a cross section that varies substantially radially with respect to the toroidal core over which they are mounted. The inventive conductor shape has

several advantages including that of providing more copper than known methods, thereby providing less resistance, and reducing flux leakage and EMI interference for the PCB.

As shown in FIGs. 1 and 5-8, each conductor 12, 32 comprises a pie-slice shaped portion having fingers 34 extending down preferably in a perpendicular direction from the plane of the pie-slice shaped portion. As is seen, these fingers 34 extend down from the arc-shaped circumference (periphery) of the pie-shaped portion. A separate finger 36 extends in the same direction from the opposite side of the pie-shaped portion. For the conductor 12 shown in FIG. 1, there are five fingers 34 extending from the arc-shaped circumference. The number of fingers is a matter of design choice. The arc-shaped circumference of the pie-slice shaped portion of conductor 32 shown in FIGs. 5-8, has four fingers 34 extending therefrom.

The use of a plurality of fingers 34 extending down from the arc-shaped circumference of the conductor are necessitated by some machining methods to avoid buckling of the conductor material. In an alternative embodiment, the portion of the conductor that extends down from the plane of the pie-shaped portion can be a solid piece, i.e., without separate fingers 34, where the conductor is manufactured by some method other than the bending of a copper sheet.

FIGs. 9-12 show conductors 42 according to a preferred embodiment of the present invention. FIG. 9 is a perspective view of a partially assembled inductor according to an exemplary embodiment of the present invention, showing three such conductors 42 positioned around a core on a printed circuit board.

FIG. 10 is a perspective view of a fully assembled inductor according to an embodiment of the present invention illustrating the placement of the remaining three conductors around the core assembly shown in FIG. 9. As can be seen, each conductor provides a segment of a loop of the winding formed around toroidal core 14.

The pie-slice shape of the conductors according to the present invention has the advantage of enabling efficient "pick and place" insertion and soldering of the conductors on the PCB using standard automated equipment. For one embodiment of the present invention each individual conductor piece is separately placed to surround the core. FIG. 11 is a top perspective view of the method and corresponding structure according to an alternative embodiment of the present invention wherein the conductors

42 are preassembled as a single unit, preferably using a non-conductive potting compound, for automated placement on the PCB. FIG. 12 is a bottom perspective view of the embodiment of FIG. 11.

As shown in FIG. 11, a potting assembly 52 is provided to enable preassembling of the conductors as a single unit. FIG. 12 illustrates the core 14 being surrounded by the pie-slice shaped conductors 42 in the potting assembly 52 prior to automated placement on a printed circuit board.

The foregoing detailed description of the invention has been provided for the purposes of illustration and description. Although exemplary embodiments of the present invention have been described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to the precise embodiments disclosed, and that various changes and modifications to the present invention are possible in light of the above teaching and appended claims.